# SWEET CLOVER FOR SOIL IMPROVEMENT

By Horace J. Harper

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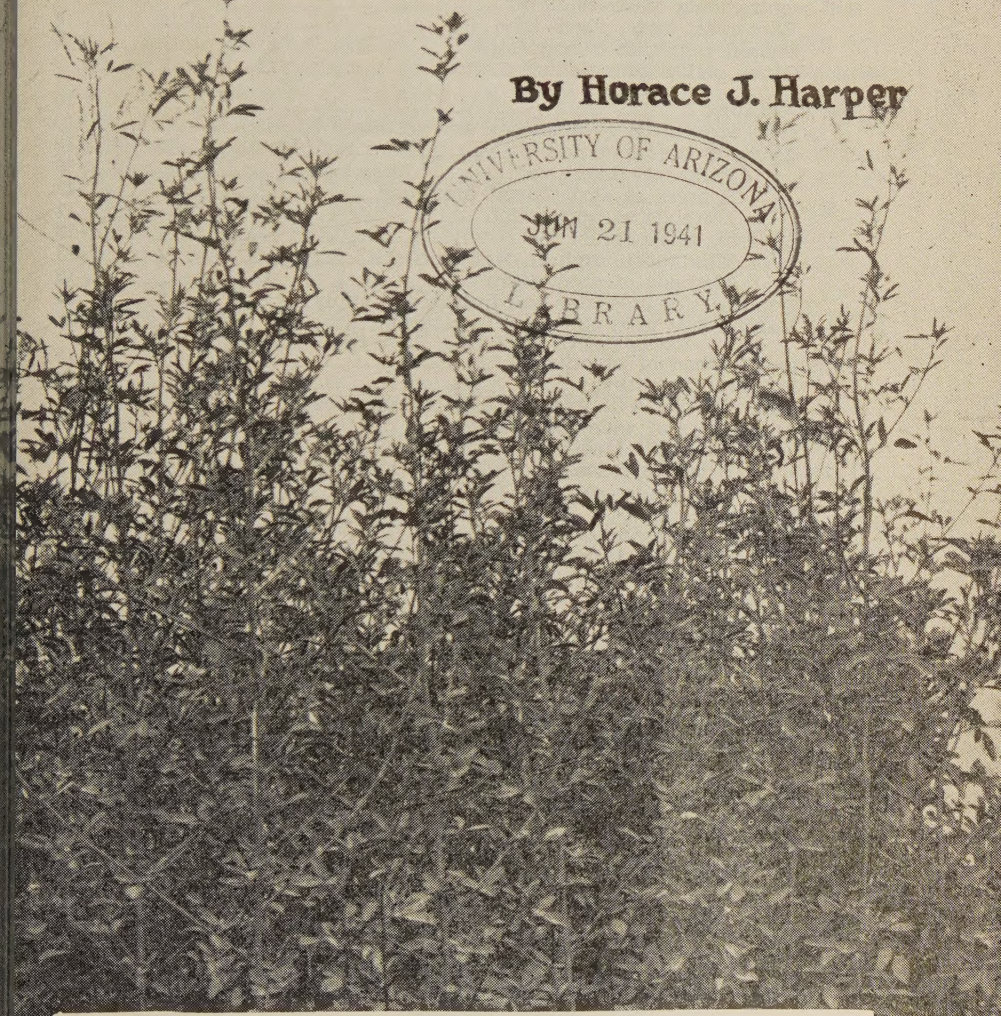

OKLAHOMA AGRICULTURAL EXPERIMENT STATION
OKLAHOMA A. AND M. COLLEGE, STILLWATER

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# Sweet Clover for Soil Improvement

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## INTRODUCTION

Sweet clover is one of the most valuable legumes which can be grown in Oklahoma to increase the nitrogen and organic matter content of cultivated land. In years past, many farmers planted this crop in an attempt to improve the fertility of their soil; but a high percentage of them failed to get a stand. Seeking the cause of this failure, soils specialists of the Oklahoma Agricultural Experiment Station found that the acidity and/or lack of available phosphorus in a large proportion of Central and Eastern Oklahoma soils prevented development of the sweet clover seedling. They demonstrated that, given enough moisture, sweet clover could be made to grow on most soils by applying lime and phosphate fertilizer.

### Wide-row Plantings Reduce Cost

The need for limestone and fertilizer, however, raised the problem of cost. The lands which most needed the fertility-restoring power of sweet clover were often worth so little that the cost of the necessary lime and phosphate was equal to the market value of the land. This problem was attacked in turn; and a method was found to make these infertile lands grow enough sweet clover to start them on the return to a higher state of fertility. This method is to plant the sweet clover in wide rows and supply small amounts of lime and fertilizer in the rows.

Wide-row planting, besides reducing the cost of fertilizer and seed, has the additional advantage of producing a stand of sweet clover under conditions where a lack of soil moisture would otherwise cause a failure, and the benefits to the soil are almost as great as if the sweet clover was planted in the usual 7-inch rows.*

* For data on results of wide-row plantings, see page 18. Experimental work with the wide-row, row-fertilized plan of growing sweet clover is described in Oklahoma Experiment Station Bulletin No. B-248, *Wide Row Spacing and Row Application of Limestone and Phosphate for Sweet Clover Production.* The object of the present circular is to describe the application of this plan, and to give other information concerning the use of sweet clover in restoring the nitrogen and organic matter content of Oklahoma soils.

**On badly eroded land southwest of Stillwater, rock phosphate and limestone drilled with sweet clover seed in 42-inch rows gave the result shown on the right. On the left, seed was planted in 42-inch rows without fertilization. Wide row-spacing with row fertilization makes it possible to grow sweet clover at a cost for seed and fertilizer of approximately $1 per acre.** **See page 18.**

## The Need for Legumes in Oklahoma

The nitrogen and organic matter content of the cultivated land in Oklahoma has decreased at the average rate of approximately one percent per year as a result of the production of soil-depleting crops and losses from soil erosion. Continuation of this loss must eventually lead to abandonment of many farms, and abandonment due to exhaustion of the soil can be prevented only by adopting cropping systems which include legumes for adding nitrogen to the soil.

Oklahoma farmers, who have been cultivating their land for less than fifty years, are not yet accustomed to a system of farming which requires soil maintenance. The rapid loss of nitrogen from cultivated Oklahoma soil makes it clear that there must sometime be an end to systems of farming in which nothing is put back into the soil to replace the fertility which is sold off the farm in the form of livestock, livestock products, or cash crops such as forage, grain, cotton, and cottonseed. *In a permanent system of agriculture, part of the money received for crops and livestock must be used to purchase limestone and fertilizer.* The percentage of the gross income which will be required to purchase plant nutrients to maintain the productive capacity of the land will depend upon the natural productivity of the soil and upon the climatic environment.

## Sweet Clover Compared to Other Legumes

There is plenty of room in Oklahoma for an increase in the acreage of *all* adapted legumes. The total acreage of legumes in Oklahoma is only one-fifth as great as it should be to prevent a further decline in the nitrogen content of the soil.

Although sweet clover is only one of several legumes which can be used for increasing the crop-producing capacity of the land, it is on many soils one of the best. This has been shown by experiments and demonstrations conducted in this and many other states, yet sweet clover is not widely grown in Oklahoma. There have been, in the past, four principal reasons:

1. Fertilization is required to grow sweet clover successfully on mineral-deficient soils, whereas there are other legumes which will make some growth on such soils without treatment.

2. Summer drought has destroyed good stands of sweet clover in the western part of the state and on claypan soils in eastern Oklahoma.

3. Unless biennial sweet clover can be seeded with a nurse crop of small grain, it will occupy the land for two years and thus still further reduce that portion of the farm devoted to growing cash crops.

**Residual effect of sweet clover on the growth of tame pasture grasses on land near Lenapah.**

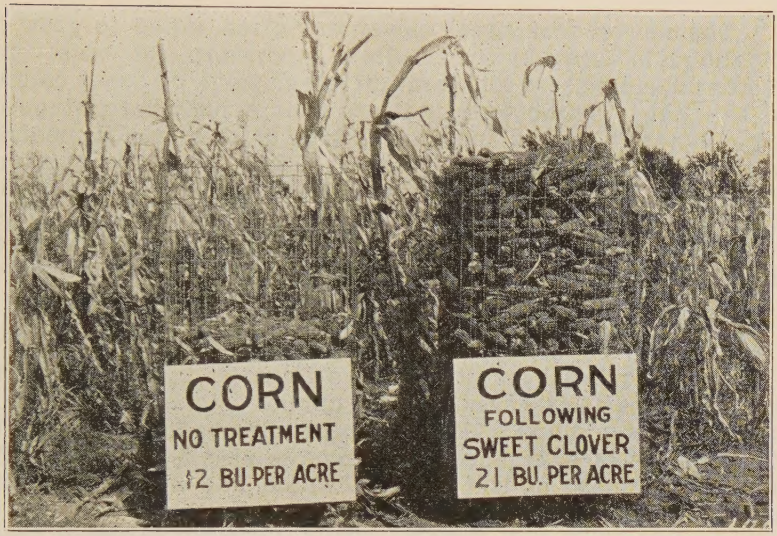
**Oats produced the second year following sweet clover on a plot near Watova. At left, following sweet clover, average yield 61.3 bushels per acre. At right, no sweet clover, average yield 32.0 bushels per acre.**

4. Farmers who do not have livestock cannot derive much income from land planted to sweet clover, although some income may be obtained from a seed crop when market demands are favorable.

The two latter reasons are primarily a matter of farm managemeent. They cannot be discussed extensively here, but it should be pointed out that in some circumstances soil exhaustion may force either a change in the system of management or abandonment of the land.

The first two reasons—cost of fertilization and crop loss due to drought—can be overcome in most parts of the state by the plan of wide row-spacing and row fertilization described in this circular.

The reason that sweet clover should be grown instead of some other legume is that it will usually add more nitrogen to the soil. This is because it grows during the fall and spring when conditions for nodule development are most favorable. Some difficulty occurs in obtaining a good production of nodules on summer or winter legumes, particularly when the season is dry. Drought not only restricts nodule development, but also causes nodules already present on the roots of the legume to




**Corn following sweet clover on a plot near Chandler benefits from nitrogen added to the soil by the bacteria on the sweet clover roots.**

disappear. Sweet clover and other legumes which grow during the fall and spring months will have a better opportunity to develop nodules than will legumes which make most of their growth during the summer, when soil moisture frequently limits plant development.

## SOIL REQUIREMENTS OF SWEET CLOVER

That sweet clover *will* make a good growth wherever moisture conditions are favorable and there is a good supply of available mineral nutrients in the soil is frequently shown in roadside ditches. A vigorous growth of sweet clover will often be seen in such locations, whereas little or no growth will be obtained from plantings in adjacent fields. Repeated tests made by soils specialists of the Oklahoma Agricultural Experiment Station have shown that applications of finely ground limestone to acid soils, or application of both limestone and phosphate fertilizers to soils which are both acid and deficient in phosphorus, will produce good yields of sweet clover when the seed is inoculated with the proper bacteria and climatic conditions are favorable for growth.*

* These tests were described in Oklahoma Experiment Station Bulletin No. 206, *Soil Fertility and Sweet Clover Production in Oklahoma.* This bulletin is no longer available for distribution, but the essential portions of it have been given in this circular.

The reason why sweet clover has often failed to grow in Oklahoma is shown by the results of laboratory tests on several thousand samples of soil from different parts of every county in the state. These tests indicate that a high percentage of the cultivated land in the eastern half of the state is medium to strongly acid. Many of these acid soils, and also many of those which are not acid, are low in available phosphorus. Either of these conditions, or the combination of them, will account for sweet clover failure. The remedy is application of limestone or a phosphate fertilizer or both.*

## Why Sweet Clover Needs Lime

Lime is needed for at least two purposes in plant growth. It neutralizes acidity; and it also supplies calcium and in some instances magnesium. Both of these are needed for the best development of a legume crop. Lime is also essential for the best development of the bacteria which add nitrogen to the soil by producing nodules on the roots of the legumes.

Sweet clover is so sensitive to soil acidity that it will not grow on many soils where corn, oats, wheat, cotton and sorghums will make a satisfactory yield. The sap from green sweet clover stems and leaves is approximately neutral in reaction. When a soil is acid, the sweet clover plants cannot secure enough limestone to regulate the reaction of the plant sap; and, as a result, the rate of growth is retarded and premature death of the plant usually occurs.

Even when the sweet clover plant survives in a somewhat acid soil, it adds little or no nitrogen because the nodule-forming bacteria are not active.

## Subsoil Condition Is Important

The acidity of the sub-soil and the amount of available phosphorus in it are especially important for the growth of sweet clover. Therefore soil tests to determine whether or not limestone and/or phosphorus are needed may give relatively erratic results unless a thorough study is made of both surface and subsurface layers.

A slightly acid surface soil with a subsoil which is neutral or basic in reaction will grow sweet clover if moisture conditions are favorable; but if the surface soil is slightly acid and

* The most accurate way of knowing what treatment a soil needs in order to grow sweet clover is to have a chemical analysis made of the soil. A limited number of such analyses can be made by the soils laboratory of the Oklahoma A. and M. College. The appendix, page 31, gives instructions for taking samples.

**In early experiments with methods of producing sweet clover economically under Oklahoma conditions, various fertilizers were drilled with the seed in 7-inch rows. On this plot near Glencoe the center plot was untreated. Basic slag was used on the plot at the left, and limestone and superphosphate on the one at the right.**

the subsoil is even slightly to medium acid, sweet clover cannot be grown without application of limestone.

Occasionally a soil may be deficient in phosphorus in the surface layers but have a good supply of phosphorus in the subsoil. Under such conditions, plant roots may obtain a sufficient quantity of phosphorus from the subsoil to make a good growth. More frequently, however, the available phosphorus in the surface soil is higher than in the subsoil, and plant growth is poor unless a phosphate fertilizer is applied or phosphorus is liberated from the decay of organic matter in the soil.

### Other Soil Requirements

Other factors being equal, acid soils high in natural fertility will produce more sweet clover as a result of treatment with limestone and a phosphate fertilizer than will soils which have been thoroughly leached or eroded and are therefore low in available plant nutrients. A favorable physical condition of the soil is also quite essential for the growth of sweet clover. Sandy soils are frequently too loose, and sweet clover seedings fail because of unfavorable moisture conditions during the seedling stage of development. Clay soils may be too compact to absorb sufficient quantities of water for optium plant growth, especially in regions of limited rainfall.

The organic matter content of a soil is not as important for sweet clover production as it is for the growth of non-legumes, except that it may have a very important indirect effect on plant development by increasing the quantity of rainfall which is absorbed by the soil.

Lack of potassium in the soil is not an important limiting factor in the production of sweet clover except on sandy soils which are medium to strongly acid in both surface and subsurface layers. A high percentage of the subsurface soils in Oklahoma contain considerable quantities of clay. Most of these clay subsoils absorb potassium from gravitational water as it moves slowly downward through the soil, and thus prevent the loss of this element by leaching. If the subsoil is not too acid, the taproot of the sweet clover plant will penetrate into it and secure enough potassium for plant requirements.

## SOIL TREATMENT

### Row Application of Limestone and Fertilizer

The principal advantage of row application of limestone and fertilizer is the reduced cost as compared to broadcast applications. This is most important, of course, in the case of 42-inch rows; but the method has some other advantages regardless of row width. A major one is the pronounced stimulation of nodule development on the roots of sweet clover in the zone where the fertilizer is applied. It is quite possible that this effect is largely responsible for the excellent results which are obtained from a small amount of fertilizer applied in the row as compared with broadcasting the same quantity of fertilizer on a similar area.

Disadvantages of the row application plan are that it increases labor at planting time and that it requires machinery which is not available on many farms. Until the necessary machinery is acquired, the method will not be used successfully. (The machinery needed is described on page 11.)

### Applying Limestone

*Kind of Limestone.*—A good agricultural limestone should all pass through a screen having openings one-tenth of an inch in diameter, and 40 percent of the material should pass through a 60-mesh screen which has 3,600 openings per square inch. This type of material is called "agstone." Coarse particles of limestone dissolve slowly and are relatively unimportant as far as the rapid neutralization of soil acidity is concerned. Lime-

stone screenings which pass through a four-mesh screen usually contain less than 20 percent of dust and should be applied at higher rates per acre in order to produce the same effect on a soil.

*Sources of Agricultural Limestone.*—For those who do not know where agricultural limestone can be obtained, the following list of Oklahoma sources has been prepared:

| Company | Office Address | Location of Quarry |
|---|---|---|
| Chandler Materials Company, | Tulsa, Oklahoma | Garnett, Oklahoma |
| Concho Sand and Gravel Company, | Oklahoma City, Oklahoma | Betts, Oilton, and Signal Mountain, Oklahoma |
| Dolese Brothers, | Oklahoma City, Oklahoma | Bromide and Richards Spur, Oklahoma |
| Independent Gravel Company, | Joplin, Missouri | Carthage, Missouri; Sulphur Springs, Arkansas;* and Marble City, Okla. |
| Solvay Company, | Moline, Kansas | Moline, Kansas |
| Standard Paving Company, | Tulsa, Oklahoma | Gray, Oklahoma |

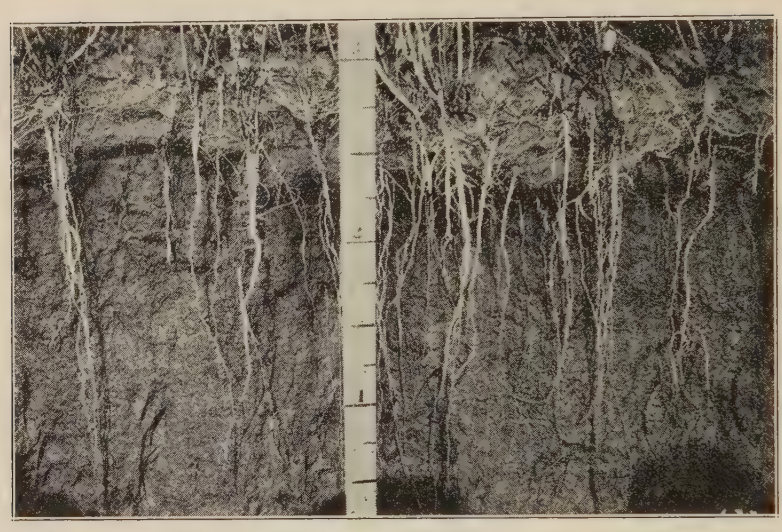
* Dolomitic limestone.

Samples and prices of agricultural limestone can be secured from the different companies on request. Local limestone crushers are available to supply finely ground limestone to a few areas in the state; however, the screenings obtained from these sources usually do not contain a high percentage of fine material when a jaw-type crusher is used.

*Methods of Application.*—Whether to apply limestone broadcast or to apply it in the row with a legume crop depends in part upon each individual farmer's circumstances. Row application is less expensive for the initial treatment because smaller quantities are applied per acre, but the equipment for making row applications is somewhat more expensive.

Row fertilization requires a combination grain drill with fertilizer distributor. The cost of such equipment varies. A small three-hole grain drill which plants the seed and distributes the fertilizer in rows about fourteen inches apart will cost about $30. Larger equipment, which is needed as the size of the farm increases, will cost from $150 to $200.

Whether to purchase a grain drill with fertilizer attachment to be used in making annual applications of limestone and fertilizer, or to spend a similar amount of money for limestone and phosphate which can be broadcast over a field once



**Sweet clover roots will penetrate compact clay subsoils after the plants once get a start. Row application of fertilizers and limestone provides the seedlings with a readily available supply of nutrients for early growth.**

every few years, is a problem which the individual farmer must decide in the development of his soil-improvement program. In the central part of Oklahoma, a good grade of agricultural limestone applied at the rate of 2½ tons per acre to a strongly acid soil should maintain a neutral condition in that soil for 15 years. The cost of a trailer type of lime spreader which can be used to scatter this type of material is approximately $35. Such a machine can be owned by several individuals, since it is not used very many days during the year by any one person. This machine will also broadcast phosphate fertilizers, although finely ground dry material cannot be spread uniformly when very much wind is blowing.

If both surface and subsurface soils are extremely acid, a sufficient quantity of limestone to neutralize the acidity should be broadcast and thoroughly mixed with the plowed layer of soil at least one year before the sweet clover is planted. The maximum effect of broadcast applications of limestone is not obtained until the limestone has been thoroughly mixed with the plowed layer of soil as a result of tillage.

During dry weather, limestone scattered on the surface of the ground and harrowed or disked into the soil has very little effect on plant development because of the limited absorption of nutrients by plant roots from the surface layer into which the limestone is incorporated.

### Applying Phosphorus

On an acid soil which is also deficient in phosphorus, application of limestone alone will not produce any appreciable increase in the yield of sweet clover. To secure the maximum effect of the limestone treatment, a phosphate fertilizer must be applied.

*Kind of Phosphate Fertilizer.*—Either superphosphate or finely ground rock phosphate may be used. Many experiments have indicated that sweet clover readily utilizes the phosphorus in finely ground rock phosphate. Rock phosphate containing 30 to 34 percent of total phosphoric acid ($P_2O_5$) can be purchased at a lower cost per ton than superphosphate containing 18 to 20 percent of available phosphoric acid ($P_2O_5$); consequently the relative cost of these materials and the availability to the farm will determine which kind of phosphate should be used.

*Methods of Application.*—If a drill with fertilizer attachment is not available, phosphate fertilizers can be applied with a trailer type of lime spreader (see page 12), although it is difficult to control the distribution when the wind is blowing.

Since the rate of application of phosphate fertilizers is usually much lower than that of limestone, fertilizers applied in drill rows seem to have a more favorable effect on the immediate crop and on succeeding crops than do broadcast applications. This is probably due to the concentration of the

**Two hundred pounds per acre of rock phosphate drilled in the row with the seed produced the second-year stand of sweet clover on the left. Row spacing was 7 inches. This plot was near Pryor.**

fertilizer in zones from which plants can obtain a more adequate supply of phosphorus than is obtained when a similar quantity of material is scattered through the plowed layer of soil.

When fertilizers are applied with a drill, they should be placed in furrows which are approximately three inches deep. The seed should be dropped or scattered on the surface of the soil above the fertilized zone. (See methods of planting, page 16.)

During seasons of limited rainfall, shallow applications of fertilizer may have little effect on plant development because root growth will take place below the soil layer in which these materials are distributed.

### Quantities of Limestone and Fertilizer to Apply

Recommendations as to the quantity of limestone and fertilizer which will be needed can be obtained from the Oklahoma A. and M. College or from your county agent after a soil analysis has been made.* The following general suggestions, however, may be helpful:

The rate of phosphorus application in rows will depend upon the width of the rows. Seven-inch drill rows will require 200 pounds per acre, 14-inch drill rows 100 pounds per acre, and 42-inch rows will require 35 to 50 pounds per acre. In all cases, twice as much finely ground limestone as phosphate fertilizer should be applied.

In row applications, the same quantity of phosphate fertilizer will be used, regardless of whether it is superphosphate or finely ground rock phosphate. On a non-acid soil, or where lime is applied, similar yields of sweet clover will be produced with the same quantity of either type of phosphate fertilizer.

When phosphates are applied broadcast, twice as much rock phosphate as superphosphate will be required. Not less than 200 pounds per acre of 20 percent superphosphate or 400 pounds per acre of rock phosphate should be applied.

When any fertilizer is applied broadcast, plant roots must come in contact with these materials before the nutrients can be utilized by the crop; consequently, within certain limits, larger applications have a more pronounced effect on yield than do smaller applications.

* See appendix, page 31, for instructions concerning the taking of samples of soil for analysis.

**A close-up of the effect of phosphate on a plot northwest of Okemah. At right, rock phosphate; at left, no fertilizer treatment.**

### Manure Best Used Elsewhere in Rotation

In fertilizer tests made by the Oklahoma Agricultural Experiment Station, farm manure applied before seeding sweet clover has usually produced no increase in yield.* In some cases, farm manure applied at the rate of 12 tons per acre did not produce as good yields as did small quantities of rock phosphate drilled in the row with the seed. The applications of farm manure stimulated development of grass and weeds which competed with the young sweet clover plants and restricted their growth during the first season.

Manure applied to some other crops in the rotation will stimulate the growth of sweet clover which is planted in following years as a result of the residual effect of important plant nutrients such as calcium, magnesium, potassium, and phosphorus which were present in the organic matter, provided they have not been utilized by previous crops.

When organic matter decomposes in the soil, phosphorus and other plant nutrients are released and can be absorbed by the plant roots. The process of decomposition is more rapid in a non-acid soil; consequently the addition of limestone will

* See Oklahoma Experiment Station Bulletin B-248, *Wide Row Spacing and Row Application of Limestone and Phosphate for Sweet Clover Production.*

indirectly increase the amount of available phosphorus in a soil high in organic matter.

Farm manure applied in large quantities may also be of value through improving the physical condition of the soil, enabling it to absorb more moisture.

## TIME AND METHOD OF PLANTING

The time and method of planting which will give best results with sweet clover vary in different parts of the state and on different soil types. Hence the following discussion can give only general recommendations, but an attempt has been made to point out as far as possible the conditions under which any particular method will be applicable.

In both broadcast and row plantings, sweet clover should always be planted on a firm seed bed. When lime is applied broadcast just before seeding time and the land has been disked to mix it with the soil, it may be necessary to roll or harrow the land several times in order to pack the seed bed.

If sweet clover is planted by the middle of September on good soil and moisture conditions are favorable, the young plants will survive the winter and make a fair growth the following year. It does not appear that fall planting will give as consistently good results as spring planting in oats or winter barley drilled in rows 14 inches apart (see page 22), because the growth the second season depends to a very great extent on the development of a large root system the first year. Fall plant-

**On this badly eroded area southeast of Prague, phosphate and limestone applied to sweet clover in 42-inch rows produced good stands, as shown at left and right. Center, no treatment.**

ing does not give the young sweet clover plant sufficient time to develop a large root system and store an abundant supply of plant food to be used in the development of a large vegetative growth the following year.

### Broadcast Planting

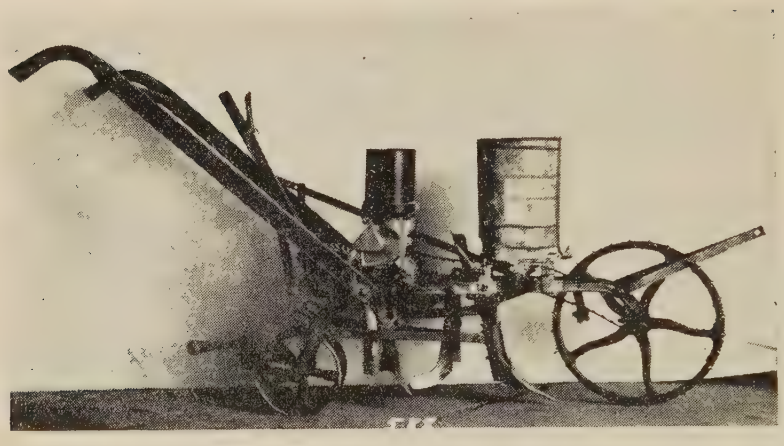
Where weeds are not a serious problem and spring rainfall can be depended upon to cover the seed, broadcasting unscarified or thresher-run seed during the latter part of February or early in March will give excellent results. The chief objection to planting in November, December, or January is that some tillage to control winter weeds or grass may be necessary. On land where severe competition from crab grass or other weeds will not occur, biennial sweet clover can be drilled as late as May first, and a good crop will be obtained the following year if the young plants are not killed the first season as a result of summer drought.

In those parts of central and western Oklahoma where spring rainfall is limited and the surface of the soil dries quickly, covering the seed seems to have some advantage over broadcasting and permitting the seed to be covered by natural agencies. Covering may be done by planting with a drill to a depth of approximately one-half inch, or by broadcasting the seed and then harrowing the land. Covering the sweet clover seed to a depth of one-half inch is not harmful unless torrential rains occur following planting and pack the soil so that the seedlings cannot push through the soil crust.

### Row Planting With Row Fertilization

If a grain drill with fertilizer attachment is available, it can be used for planting sweet clover and applying fertilizer in rows of any desired width by closing the proper holes. The major portion of the fertilizer should be placed three inches below the surface of the ground. The sweet clover seed can either be scattered on the soil above the fertilized zone by removing the seed spouts and permitting the seed to drop on the loose soil ahead of the drags or press wheels behind the disks, or it can be broadcast at a rate which will insure a good stand of plants. If the seed and fertilizer are permitted to drop through the same spout on the drill, either the seed will be covered too deeply or the fertilizer will be located too near the surface of the ground.

In most of the row-planting experiments with sweet clover which have been conducted by the Oklahoma Agricultural Experiment Station, the fertilizer was drilled in the row at the



**This one-row combination planter and fertilizer distributor was used in seeding many of the experimental wide-row plots. The original seed box using a disc plate was replaced with a cylinder planter which gave more even distribution of the sweet clover seed.**

time the seed was planted, using the one-row planter pictured above. A corn planter having a fertilizer attachment was rebuilt by replacing the planting box with a cylinder planter. This type of planter will handle small seeds better than an ordinary flat plate which is used to plant grain sorghums, although small holes may be drilled in a flat plate to handle sweet clover seed in a very satisfactory manner. Sweet clover seed may be mixed with corn meal or other finely pulverized material in order that a plate for planting sorghums can be used.

### Advantages of Wide-row Planting

*Low Initial Cost.*—Many of the soils which most need the organic matter and nitrogen provided by sweet clover have a low agricultural value based on their immediate crop-producing capacity. If enough limestone and phosphate fertilizer to fit the land for growing sweet clover were applied in the usual way and the clover planted in 7-inch rows, the cost would frequently be equal to the value of the land. But if the sweet clover is planted in rows 42 inches apart, and the limestone and fertilizer applied in the rows, only one-sixth as much limestone and fertilizer is needed.

In tests made by the Oklahoma Agricultural Experiment Station, successful stands of sweet clover were produced by using 66 pounds of limestone and 33 pounds of rock phosphate per acre. The cost of seed and fertilizer for this treatment was approximately $1 per acre.

*Drought Resistance.*—In dry years, on droughty soils, and in areas where rainfall is limited, the wide-row planting frequently will survive when plants in 7-inch rows cannot secure enough moisture to keep themselves alive. This was demonstrated in the drought year of 1934, when experimental plantings in wide rows survived while plantings in narrow rows in the same location failed for lack of moisture.

*Benefit to Soil.*—Large sweet clover plants in 42-inch rows will benefit the soil almost as much as will the more numerous small plants in 7-inch rows. Under some conditions, such as drought, the benefit will be even greater.

The idea of experimenting with the wide-row plantings came to experiment station workers when they observed the marked improvement in following crops sometimes produced by poor stands of sweet clover. Thin stands of sweet clover

**Under conditions of limited moisture, 42-inch rows of sweet clover produce about as many pounds of roots as are produced in 7-inch rows. Upper row of plants grew in rows drilled 7 inches apart. Lower plants were planted in rows 42 inches apart, and weeds were controlled by cultivation. More nitrogen at less cost for seed and fertilizer is the result.**

**Wide row-spacing will not produce sweet clover if soil conditions are not suitable. At right is second-year growth of sweet clover in 42-inch rows treated with limestone and rock phosphate. At left is a plot where sweet clover was planted in 42-inch rows without lime or fertilizer. Plot located southeast of Guthrie.**

tend to produce large plants when competition from weeds and grass is not too severe, and may add as much nitrgen to the soil when the crop is plowed under as will a large number of small plants growing close together. This is explained by the greater root growth per plant in the thin stands. By carefully spading out the roots to a depth of one foot in equal areas from plots of wide- and narrow-row plantings, experiment station workers found an average of 1,215 pounds per acre from plots in 7-inch rows and of 1,175 pounds per acre from plots in 42-inch rows.

### Rate of Seeding

When sweet clover seed is broadcast or drilled in 7-inch rows, 15 pounds of good clean seed per acre will usually give a good stand. When the seed is drilled in single or paired rows spaced from 36 to 42 inches apart, from three to six pounds per acre is adequate.

Larger quantities of thresher-run seed should be used, since it is not the number of seed per square foot but plant survival that affects the stand. Under unfavorable conditions, the first stand of sweet clover may be destroyed by freezing and the second stand by dry weather; consequently, enough seed must be used to provide a third stand, which will make the crop unless it is killed by summer drought. Scarified seed tends to germinate evenly, and this is one reason why such seed should not be used for early planting.

### Contour Listing to Save Moisture

Contour planting in shallow lister furrows will increase the yield of sweet clover in regions of limited rainfall. Lister furrows on the contour absorb rainfall and provide a very favorable condition for the growth of a crop like sweet clover which can obtain its nitrogen from the air.

One problem occurs, however, when sweet clover is planted in lister furrows. If the soil is mellow or loose, torrential rains may partially fill the furrows with soil and cover the seed so deeply that the young plants cannot reach the surface of the ground, or may destroy the young plants by covering them with soil after they have emerged. This hazard can be eliminated to a very great extent by listing the land about two or three inches deep early in the winter and planting the sweet clover after rainfall has stabilized the soil on the sides of the lister ridges.

On soil affected by wind erosion, lister furrows may be filled or the young plants damaged by wind-blown soil. Protection from this can be provided by planting sweet clover on land where grain sorghum was grown the preceding year, or in cane or Sudan grass stubble. This will also reduce the competition from weeds and grass, which is an important factor in the success of sweet clover in western Oklahoma.

Planting in sorghum stubble, however, may fail to produce maximum yields when the subsoil is dry at planting time and very little rain falls in late fall or winter. Under such conditions, the successful growth of sweet clover will depend upon the amount of spring and early summer rainfall, since a dry subsoil is unfavorable for production of maximum yields.

### Paired Rows for Producing Forage

Experiments conducted at the U. S. Dry Land Field Station near Lawton, Oklahoma, indicate that paired rows of sweet clover may have some advantage over single rows for forage production. With this method of planting, twice as many plants will occur on the land and each row will have a considerable area from which moisture can be obtained, especially when the land between the rows is cultivated during the first season to control weeds and grass.

Paired rows can be obtained by drilling the sweet clover with a grain drill and closing the proper number of openings to give the required spacing. When the disks on the drill are spaced eight inches apart, three of the openings should be

closed and two left open, which will make the center of the paired rows 40 inches apart. When the disks are spaced seven inches apart, four of the seed boxes should be closed and two left open, which will make the center of the paired rows 42 inches apart.

## NURSE CROPS

### Types of Crops

Spring oats, flax, and winter barley are good nurse crops for sweet clover.

Winter oats, rye, and winter wheat are not favorable. They establish a surface root system in the soil in the fall, removing available moisture which may be needed for the early development of the sweet clover. They also make a tall, vigorous growth, which shades the young sweet clover plants and restricts their development the following spring.

### Rates of Seeding

When sweet clover is planted with a nurse crop, decreased rates of seeding the grain are advisable under Oklahoma conditions. A decrease in the rate of seeding small grain within

**To prevent competition for moisture between sweet clover and a nurse crop, the nurse crop can be planted in 14-inch rows. Tests have shown that the yield of grain is not greatly reduced. This picture shows Madrid yellow biennial sweet clover in stubble of winter wheat planted 14 inches apart on the Oklahoma Agricultural Experiment Station farm at Stillwater. The sweet clover was drilled between the rows of wheat about March 1. Oats and winter barley are better than winter wheat or rye as nurse crops for sweet clover.**

certain limits does not decrease the yield, because the number of culms is increased when plants are spaced a considerable distance apart. *By closing every other opening in a grain drill and planting about 1¼ bushels of oats per acre, the opportunity for legume seedlings to survive can be improved without appreciably reducing the yield of grain.*

Results obtained in tests at Stillwater show that the yields of spring-planted oats, barley, and wheat are reduced but little by the 14-inch spacing as compared to 7-inch spacing. The oats were planted during the latter part of February, and sweet clover was planted between the rows of oats about the middle of March. The wheat was planted in the fall in rows 14 inches apart, using approximately 38 pounds of seed per acre; and the sweet clover was planted between the rows of wheat the following spring about March 1. The picture on page 22 shows sweet clover growing in wheat stubble following harvest. Barley and oats planted in 14-inch rows have produced nearly as much grain per acre as in 7-inch rows, and sweet clover planted between the rows has survived and produced very satisfactory yields where soil conditions were favorable for it.

In the western part of the state, a row spacing even greater than 14 inches will be necessary to prevent the nurse crop from competing with the sweet clover for moisture.

Since by planting the nurse crop in 14- or 16-inch rows a good stand of sweet clover can be obtained under conditions where failure otherwise would result unless rainfall is very favorable following harvest, this method should be used more extensively to grow sweet clover for replacing the nitrogen lost when soil-depleting crops are removed from cultivated land.

A good stand of lespedeza can also be obtained by using this method of planting the nurse crop.

### Using Nurse Crop to Control Weeds

On areas where weeds and grass compete with young sweet clover plants during the first season, a thin planting of small grain may be distinctly benficial. The small grain ceases to withdraw moisture from the soil after the crop matures, whereas many kinds of weeds and grass continue to grow and compete with the sweet clover plants for available soil moisture during the summer.

## SEED INOCULATION

Alfalfa, bur clover, and black medic cross-inoculate with sweet clover. When these crops have been grown on a soil and produced an abundance of nodules, conditions will be favorable for the natural inoculation of sweet clover. Although natural inoculation occurs in a majority of the bottom lands where alfalfa is usually planted, sweet clover bacteria are frequently absent in upland soils; consequently inoculation is recommended as a relatively inexpensive insurance against sweet clover failure.

### Inoculation Always Needed After Liming

When sweet clover is planted on soil where limestone is being applied to correct soil acidity, the seed should always be inoculated. Sweet clover bacteria soon perish in acid soil; therefore if it is necessary to lime the soil it is almost certain that there are no sweet clover bacteria living in it.

### Methods of Inoculation

*With Soil.*—Legume seed can be inoculated with commercial cultures or with soil. If the soil method is used, a composite sample should be secured from a field where an abundance of nodules was produced on the roots of the legume crop and a suspension prepared by shaking one part of soil and two

**Inoculation is good insurance for any planting of sweet clover, and if the soil has been treated with limestone to correct acidity it is absolutely necessary. Even though some growth is secured without inoculation, fewer and less vigorous plants are developed and little or no nitrogen is added to the soil. The picture above shows inoculated sweet clover at the right, and an uninoculated plot at the left, on a field southwest of Mulhall.**

parts of water in a two-quart jar or stirring the water and soil in a pail. After the sand has settled to the bottom of the container, which will require one or two minutes, pour off the muddy water and mix it with the legume seed. Allow the seed to dry in a shady place until they will not adhere to each other, and plant immediately.

*With Commercial Cultures.*—Although the use of commercial cultures of bacteria is more expensive than the soil method of inoculation, it eliminates the danger of introducing plant disease with the soil obtained from another farm. It also increases the likelihood of obtaining successful inoculation, because many companies which prepare commercial inoculation make an effort to maintain more vigorous strains of nitrogen-fixing organisms in their cultures than are present in the average soil.

The cost of inoculating legume seed with commercial culture will vary from 5 to 10 cents per acre, depending upon the rate of seeding.

Legume cultures deteriorate with age unless they are stored in a cool place. Consequently, only inoculating material which is less than a year old and has been stored under favorable conditions should be used.

### Sources of Commercial Cultures

If commercial cultures of legume bacteria cannot be secured locally, they can be obtained directly from companies which manufacture them or from commercial seed houses.

Sources of legume inoculation in Oklahoma include:

Chickasha: Oklahoma Improved Seed Company
Enid: Johnson Seed Company
Muskogee: Oklahoma Seed House
Oklahoma City: Hardeman-King Seed Company
Shawnee: Clarke and Keller Seed Store
Tulsa: Binding-Stevens Seed Company

Companies which manufacture legume inoculation include:

A. Dickinson Company, Chicago, Illinois
Hansen Inoculator Company, Urbana, Illinois
Kalo Inoculant Company, Quincy, Illinois
The Nitragin Company, Milwauke, Wisconsin
Urbana Laboratories, Urbana, Illinois

## VARIETIES

There is a marked difference in the growth of sweet clover varieties; consequently, the purpose for which the crop will be used must be considered. For soil improvement, varieties which will make a maximum yield of forage are more valuable than those which produce a smaller growth.

Experiments indicate that Madrid yellow sweet clover has an advantage over many other varieties because: (1) The seedlings grow more rapidly and compete to better advantage with other vegetation; (2) the stems are not too coarse for grazing; (3) the variety produces a good yield of forage; and (4) it will mature seed before summer drought occurs.

Adapted strains of white biennial sweet clover are also satisfactory. Some varieties of sweet clover produce large yields of seed but do not produce large yields of forage; consequently, seed should be obtained which will produce a tall, vigorous plant in order to add a maximum amount of nitrogen to the soil.

### Disease Resistance

Plant diseases are not at present an important limiting factor in the production of sweet clover in Oklahoma, but it is possible that they may become more important as the acreage of sweet clover increases. Leaf spot diseases frequently appear on many varieties when weather conditions are favorable for their development. On soils which have slow internal drainage, certain diseases may affect sweet clover during periods of abundant rainfall. Observations in eastern Oklahoma indicate that it may be necessary to plant disease-resistant strains of sweet clover on poorly drained land where conditions are more favorable for the development of diseases which restrict the growth of this crop.

### Annual vs. Biennial Sweet Clover

One of the objections to biennial sweet clover has been that it occupies the land for two years, and therefore, under average conditions, very little income can be obtained from the land unless a livestock system of farming is used. Even if livestock is grown, heavy pasturing the first season will frequently kill the sweet clover plants or reduce the yield which should be obtained the second year on many soils; consequently, grazing during the first season must be carefully controlled in order to obtain maximum yields the following year.

Annual white sweet clover can be grown for soil improvement in areas where summer drought interferes with the normal development of biennial sweet clover. The annual type has made a fair growth when planted with spring oats planted in rows 14 inches apart, and may be used in a continuous small-grain cropping system on soils which are not acid and contain a good supply of available phosphorus. More extensive experiments are needed before the proper utilization of the annual type of sweet clover can be determined, but the results of tests conducted to date indicate that more attention should be given to the use of annual sweet clover for soil improvement in the central and western parts of the state.

Very little is known concerning the pasture value of annual sweet clover, but it has reseeded effectively in several areas. Since it matures in July, it will not produce fall pasture; but it should be of value in a small-grain cropping system, since summer moisture can be conserved and the land can be planted to winter oats, barley, wheat or rye during the latter part of September or early in October.

Results published by experiment stations in the Corn Belt indicate that biennial sweet clover is superior to annual sweet clover from the standpoint of increasing the yield of corn and oats. The annual type may nevertheless have some advantage in certain parts of Oklahoma where biennial sweet clover has failed due to summer drought even when planted under favorable conditions. Even when the biennial sweet clover does survive summer drought in areas of low rainfall, it exhausts the subsoil moisture and therby produces an undesirable condition if the moisture is not replaced by favorable rainfall before the following crop is planted. Annual sweet clover planted in March on soils which are not acid and contain a good supply of available nutrients will usually mature before severe drought occurs, since it will make the major portion of its vegetative growth by the first of July. Crop residues from annual sweet clover can be plowed under in July, permitting soil moisture to accumulate in August and September. This cannot be done when summer legumes such as cowpeas, soybeans, and lespedeza are grown.

## USING SWEET CLOVER GROWN FOR SOIL IMPROVEMENT

When sweet clover is grown for the purpose of soil improvement, any use made of the plants must be such that all of the vegetation is returned to the soil where it grew. Pasturing the sweet clover is one method of accomplishing this.

### Pasturing Sweet Clover

Sweet clover is a valuable pasture crop, but it should not be grazed too heavily the first season. Pasturing the young sweet clover after small grain is harvested will prevent maximum root development, which on the average soil is essential for the production of a large growth of sweet clover the following year. Most of the root growth is made the first season. During the late fall and winter, the top growth of first-year sweet clover can be grazed without damage to the spring growth.

When the second year's growth begins to appear, livestock should be removed from a sweet clover field and grazing should not start again until the plants are about six inches high. The heaviest pasturing of sweet clover should come in the second year for best results. If livestock are removed from the field when the sweet clover begins to bloom, a seed crop can be harvested provided moisture conditions are favorable for growth during that period of the year.

On farms where sweet clover cannot be utilized by livestock, a seed crop will provide some income from the land if a market is available. When sweet clover is harvested for seed with a binder, the stems should be returned to the land so that the nitrogen in them will be available for succeeding crops as the stems decay.

### Differences in Crop Response to Sweet Clover

The greatest increase in yield as the result of plowing under a crop of sweet clover on a nitrogen-deficient soil will be given by winter grains. The least response, on the average, will be obtained from grain sorghums. The relative influence, from greatest to least, is shown by the following list:

Winter barley.
Winter oats.
Winter wheat.
Spring oats.
Corn.
Cotton.
Sorghums (for grain).

If forage production rather than grain yields is considered, the list would be arranged somewhat differently, since the effect of surplus nitrogen is to increase the vegetative growth of the plant rather than the seed production.

### Crops Following Sweet Clover Need Careful Management

When small grain or row crops are planted on land where sweet clover was grown the previous year, a marked increase in vegetative growth of the following crop will occur if climatic conditions are favorable. This increase is due to the large quantity of nitrate nitrogen which is liberated as a result of the decomposition of the sweet clover residues.

When the following crop is planted in drill rows seven or eight inches apart and there is a deficiency of available moisture near the end of the growing season, which is a common condition in central and western Oklahoma, an increased vegetative growth may result in a reduced grain yield because of the combined effect of the increased moisture requirement of a large vegetative growth and a limited supply of available moisture in the subsoil. This condition can be regulated to a very great extent by planting the small grain in wider rows to reduce the number of plants per unit area and by planting the small grain later in the fall to conserve the moisture in the surface soil.

Winter grazing or early spring grazing to reduce a vigorous vegetative growth may also be helpful under certain conditions for the best utilization of a limited supply of soil moisture.

Weeds or grass may be controlled between wide rows of small grain under average conditions by harrowing or the use of some other suitable means of tillage during the latter part of the winter or early spring to destroy the young plants before they are firmly rooted in the soil.

### Sweet Clover for Reestablishing Grass

On many areas of abandoned land, native grass does not return rapidly. Since the seed of the more desirable species of grass is not carried very far by the wind, subclimax species composed of annuals, biennials, and inferior perennials cover the ground where erosion has not completely removed the surface soil. Abandoned eroded areas which have been under observation for periods varying from 15 to 20 years have not yet developed a good stand of native grass composed of little bluestem or other desirable species. The eventual return of climax grasses may depend upon the fertility and a favorable physical condition of the soil.

Under such conditions, row fertilization with sweet clover may have a distinct advantage from the standpoint of improving the nitrogen content of the soil so that introduced grasses

such as Bermuda could be planted in lister furrows after the sweet clover has been grown. Bermuda grass under such conditions may not behave as a climax species, but it will supply some grazing the first season it is planted. It is also not as seriously damaged by overgrazing as are little bluestem or other native grasses which can be grown on poor soil.

On the soil conservation experimental farm at Guthrie, Oklahoma, a row planting of Madrid yellow sweet clover was made in 1935. It was fertilized with 50 pounds of rock phosphate and 100 pounds of limestone per acre. The sweet clover has reseeded in the fertilized rows, and a good growth was still present in these rows in the spring of 1939. This area of land had been damaged severely by sheet and gully erosion before it was abandoned from cultivation. Where the surface soil had been largely removed by erosion, the ground between the sweet clover rows is bare; but where the combined effect of the limestone, the phosphate fertilizer, and the growth of the sweet clover has improved the fertility of the soil there is a good growth of perennial grasses. On an adjacent area where sweet clover was planted but failed because no fertilizer was applied, only a scattered growth of these grasses has appeared.

## APPENDIX

### Gathering Soil Samples for Analysis

The chemical composition of a soil is only one of many factors which may affect successful production of a crop; consequently, a soil analysis followed by the recommended soil teatment is not by itself enough to insure plant growth. Nevertheless, it is possible to determine by an analysis whether a deficiency or an excess of any of the substances for which tests are made may be responsible for poor plant development.

The Agronomy Department of the Oklahoma A. and M. College, Stillwater, Oklahoma, will make without charge a limited number of soil analyses for acidity, available phosphorus, available potash, and total soluble salts for anyone who owns or operates land in the State of Oklahoma.

In collecting samples to be sent for analysis, prepare a composite sample of surface soil representing the plowed layer, which is usually about six inches deep, and a composite sample of the subsurface soil taken at a depth of 15 to 18 inches, for each kind of soil in a field or plot. To prepare a surface composite, six or seven small samples of surface soil should be obtained and mixed together; and for the subsurface composite at least three samples should be obtained and mixed together. The total quantity of each sample should be about one pound.

Number each surface and subsurface sample so that it can be easily identified. A suggested plan of numbering is: Surface No. 1, Subsurface No. 1; Surface No. 2, Subsurface No. 2; etc.

Send with the samples a letter indicating the problem as it appears to the land owner, the crops to be grown, and the depth at which clay occurs in the soil. The latter information is necessary because shallow surface soils are frequently responsible for the poor yield of crops which grow during the summer months, especially in years when the distribution of rainfall is not favorable for plant development.